Interactive Museum Exhibit to Introduce K-6 Grade Students to Circuits and the Electric Conductivity of Various Materials

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Table of Contents

Acknowledgements ... i
Table of Contents ... ii
Table of Figures ... iv
List of Tables ... iv
Abstract ... v
1 Introduction ... 1
1.1 Background ... 1
1.2 Stakeholders and User Personas ... 2
1.2.1 Students ... 3
1.2.2 Curator ... 3
1.2.3 Teachers ... 4
1.2.4 Volunteers ... 4
1.2.5 Parents ... 4
1.3 Design Requirements and Constraints ... 5
2 Design Process ... 5
2.1 Identify Users and Stake Holders ... 5
2.2 Defining Design Requirements and Constraints ... 6
2.3 Design and Prototype ... 6
2.4 Testing and Modifications ... 7
3 Results and Discussion ... 8
3.1 Topic Choice ... 8
3.2 Design ... 9
3.3 Materials ... 12
3.4 Circuitry ... 14
3.5 Prototype ... 15
3.6 Testing ... 15
3.7 Final Design ... 16
4 Conclusion ... 18

5 References 19
6 Appendices 20
6.1 Appendix A – Materials Sorted by Resistivity in CES 20

Table of Figures

Figure 1. A sample user persona created for a kindergarten student. 3

Figure 2. The initial 2.5' x 2.5' museum exhibit design contained eight circuits. 9

Figure 3. Components on the finished prototype place at SciTech for observations. 10

Figure 4. Diagram of how students will interact with the exhibit. 11

Figure 5. Complete ProEngineer model of the prototype design. 12

Figure 6. a) Schematic of a series circuit showing the two empty slots in a straight line. b) Schematic of a parallel circuit showing the empty slot of the materials side by side. 14

Figure 7. The current in the circuit containing each individual material showing which ones lit the LED. The two metal samples were able to complete the circuit lighting the LED while the other material were not conductive and did not light the LED. 14

Figure 8. Completed prototype made from 1/4" plywood. 15

Figure 9. Observations were taken while the students interact with the finished prototype at the SciTech. 16

Figure 10. Components on the final museum exhibit design. 17

List of Tables

Table I. List of Possible Materials from CES with Chosen Materials Bolded 13

Abstract

The SciTechatorium (SciTech) is a museum filled with interactive exhibits for visitors to learn science informally. A new exhibit was developed to explore electric conductivity and circuits. The design was made based on the size of the material sample the students will use and to allow interactions with multiple users. The materials the students will use were selected using Cambridge Engineering Selector (CES) to sort the materials by resistivity, the inverse of conductivity. After sorting the materials by resistivity, five different materials (balsa wood, polystyrene, polyester, stainless steel, and copper) were chosen for the exhibit. The target size of the materials was 6 x 0.75 x 0.25 inches. The size of the materials is thin enough for the children to hold, but large enough to be easily visible and handled. The frame of the exhibit was made to be 36 x 24 inches to provide ample space for students and to incorporate four independent circuits, two parallel and two series circuits. A light emitting diode and an ammeter were added to provide students with a qualitative and quantitative method of verifying the conductivity of the materials. Since metal is a good electrical conductor, a 220 Ω resistor was added to the circuit so that the current going through the LED does not exceed 30 mA and burn out. The 6 V power source is used and will not be able to shock anyone. A complete prototype was made from plywood to observe student interactions before the final product is made from transparent acrylic so the students will be able to see the circuit wiring. The observations from the interaction with the prototype guided the modifications of the final design.

Keywords: Materials Engineering, SciTechatorium, exhibit, museum, circuits, design

1 Introduction

Informal science is learning science outside of the classroom setting. There are many methods to experience informal science from staying at home and watching The Magic School Bus to visiting a science museum with interactive exhibits such as the Exploratorium or Tech Museum. Experiencing informal science, students are able to learn new concepts or reinforce their science knowledge by having fun and exploring at their own pace. Many science museums, if not all, have visitors come play and learn from the interactive exhibits. The SciTechatorium in Avila is no different.

The SciTech is a non-profit independently operated museum located at the Bellevue-Santa Fe Charter School, and is open for students and community members to use and learn about science. The museum operates on donations from visiting schools and community members to obtain new exhibits and maintain the current ones. The mission of the SciTech is to help the students at the charter school, as well as visiting students from the local schools, to learn about science and technology by exploring the numerous interactive exhibits on display. Since the SciTech operates on donations, they welcomed the opportunity to receive a new exhibit from Cal Poly students.

1.1 Background

Informal science is for people of all ages and is a lifelong process that can occur during everyday living. People learn from observations, conversations, and even just wondering how something works. Humans are naturally curious, social, and active people and informal science can satisfy all three needs[1]. Informal science education allows people to engage in science without using a text book or being lectured, but from playing and exploring at their own pace and what they want just as the National Science Foundation states:

> "Informal learning happens throughout people's lives in a highly personalized manner based on their particular needs, interests, and past experiences. This type of multi-faceted learning is voluntary, self-directed, and often mediated within a social context. It provides an experimental base and motivation for further activity and subsequent learning."
>
> - National Science Foundation[2]

People can learn from informal science by visiting a number of science centers or museums all over the United States. Science centers serve three main purposes: to connect people with science, to provide firsthand experience with science, and to encourage curiosity[3]. Many of the science centers have interactive museum exhibits for people to explore. A common way to interest people in science is to allow them to experience for themselves the amazing phenomenon. Just like designing for any client, museums have clients to gear their exhibits. Some characteristics that successful museum exhibits have in common are present the exhibit, involve the visitors, accommodate different learning styles, promote social learning, considering the cost of the exhibit, test, and redesign[4]. Museum exhibits can be one of the hardest products to design with such a large range of audience.

A wide range of exhibits have been successfully placed in science centers from biology, circuits, electricity, turbines, earthquake simulators, planetariums, and much more. Even though some exhibits from different science centers have a similar topic, the way the user interacts with the exhibit is different. For example there is an exhibit called Electric Circuits[5] and another called Series/Parallel Circuits[6]. Each exhibit has to do with electricity and circuits, but the interaction of the Electric Circuits is similar to Legos. Each component of the circuit is encased in insulated material with only certain sides exposed. The users would take the pieces and place them on the guide mats that are connected to the power source. This exhibit allows the users to experiment with circuits, but does not allow the users to create their own, only ones that are on the guide mats. Whereas the Series/Parallel Circuits exhibit are more design based. The components are also encased, but the power source is movable. This allows for the exhibit to be manipulated in more ways providing the user with the freedom to experiment. Each exhibit has the capability to allow the user to experiment with circuits, but each is also unique it small ways. Designing a completely new exhibit is difficult and can cost a vast amount of money to test and retest. The exhibits all have a different interaction level with the users even if they seem to be similar.

1.2 Stakeholders and User Personas

After observing the interaction with existing museum exhibits at the SciTech, it became clear that the audience is not only the students, but also the curator of the museum, teachers, parents, and volunteers. Each group of people has different needs and expectations of what an educational museum exhibit should include. In order to understand the needs of each individual group, user personas were made. The user personas are a key tool in designing any product. Creating realistic profile of a person, designers can then create a product based on the predicted user interaction.

1.2.1 Students

The students are the main focus of an interactive science museum exhibit. Many exhibits are designed to tend to their needs such as size, interaction level, and safety. One of the student personas created was a kindergarten student, the youngest age group at the charter school (Figure 1). Little Tommy is only 3' tall and has short arms. The persona was created to estimate possible users, and the worst case scenario is the smallest student attending Bellevue-Santa Fe Charter School. The exhibit needs to be designed so that smaller students will not be left out. To account for the size of the younger students, the exhibit must be an appropriate size so that even the smallest student will be able to interact with the exhibit without much trouble. It is also in the nature of young children to want to grab everything within reach, so the components of the exhibit will have to contain rounded edges, and avoid any potential misuse from students that will cause them or others harm.

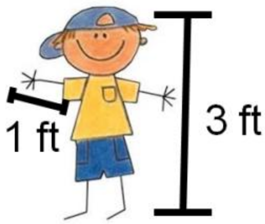

Figure 1. A sample user persona created for a kindergartener student.

One main need for the student is to learn. Although each student learns something different when they interact with the exhibits, each one can socially interact with one another and with the museum guides to practice communication skills.

1.2.2 Curator

SciTech's curator, Chick Fedel, is one of the main stakeholders of all the museum exhibits. He is responsible for the safety of visitors and the interaction between the visitors and the exhibits as well as each other. Mr. Fedel facilitates and encourages students to learn and explore science together. The curator's job is also to maintain the existing exhibits, and reaches out to the community members for donations and volunteers. Because SciTech is independently operated, some of the maintenance comes out of pocket for the curator. Keeping the financial status of the museum in mind, the exhibit must be low maintenance and durable. In the case of something breaking, the materials should be able to be found at local hardware and electronic supply stores (i.e. RadioShack, Home Depot, and Ace Hardware). Another concern of the curator is the safety of the students and visitors of SciTech. Since the users of SciTech's exhibits range from kindergarten students to adults, the exhibit must be safe in all aspects from the frame to the interaction of the components of the exhibit.

1.2.3 Teachers

Visiting students from other schools usually take a class trip to explore science at the SciTech. A lot of times the teachers are the facilitators to these exhibits and encourage students to explore science by interacting with the exhibits. While teaching the students the importance of learning through interaction with the exhibits, some teachers, especially the science teacher at Bellevue-Santa Fe Charter School, visit SciTech to use certain exhibits as demonstrations for certain complex concepts.

1.2.4 Volunteers

The volunteers (also called docents by SciTech) are the main facilitators between the students and the museum exhibits. Docents can be current student volunteers from Cal Poly or Bellevue-Santa Fe Charter School, parents of students, or community members. Docents encourage the visitors to interact with the exhibits and not to be afraid of touching anything. The docents also carry the responsibility of helping the curator monitor proper use of all exhibits and explaining the general science information of certain exhibits. It is important to note that not all the volunteers have a strong science background, so some guidance is required before the volunteers can effectively communicate the information to the students. The exhibit cannot be an overly complex theory because the docents are not all scientists, and should be able to be easily explained or understandable for both the docent and visitors.

1.2.5 Parents

Parents are crucial stakeholders in a child's education. Their expectations are high especially if they are entrusting their child to the teachers for 6-7 hours a day, 5 days a week. Many parents trust schools to teach their children the right thing, this is called "in loco parentis" or in place of parents. In trusting their children to schools or allowing them to visit the museums, the organization holds the responsibility to educate the students properly. The standards of the parents are most likely the highest of all the groups. Sometimes the parents chaperone the class to SciTech and interact with the students and exhibits. The parents then become participants and evaluate which exhibit does its job at educating the students. Parents can play the role of a volunteer as well, and have similar needs.

1.3 Design Requirements and Constraints

After observing at SciTech a few times, there are a few things noted about the interaction between the students with each other and with the exhibits. Many museum exhibits were used as a social gathering medium. The students would gather, play, explore, and learn together and from each other. Most if not all of the younger students do not understand the complicated theories behind some exhibits, but they are introduced to new science topics that may be learned later in their lives. Based on the observation data and user personas created, several project goals were formed for the exhibit:

- Allow students to "learn by doing" through discovery
- Allow students to work as a team and communicate information
- Provide a safe exhibit for the students to interact and learn
- Encourage to students to explore and ask questions that may lead to higher learning
- Encompass portions of the California state science standards
- Form connections to their everyday life
- Allow students to test different situations based on their hypothesis

2 Design Process

The design process of creating a museum exhibit encompasses several different steps. Each step is crucial in designing any type of product for clients. The steps demonstrate user centered designing.

2.1 Identify Users and Stake Holders

The first step to designing any consumer product is to understand the users and stakeholders. As mentioned in section 1.2, a common practice is to create user personas to visualize the clients and focus on their needs. A persona is created for each person with names, physical characteristics, personalities, and hobbies. Creating a persona is similar to creating a fictional television character. The more realistic the person seems, the easier it will be to imagine the user interacting with the product.

2.2 Defining Design Requirements and Constraints

After the users and stakeholders are identified, the user personas can be used to create design requirements and constraints for the exhibit. The design requirements and constraints will help the designer narrow down the possible topics for the exhibit. The design requirements and constraints are an important part to making any product. Without the proper requirements, the target audience will not be interacting with the exhibit the way it was intended. Identifying the requirements can be systematic with the user personas. Going through each persona one at a time, the designer can create a list of needs for the particular user. When all the personas are done, the lists can be combined and edited.

Working with SciTech, some special design requirements were given due to the size and financial independence of the museum. The SciTech is a small museum that contains many exhibits from all areas of science, which leads to the lack of physical space in the museum for new exhibits. The size of the exhibit is restricted for display and mobility reasons, as well as for smaller students. An appropriate size for the exhibit must be considered for the youngest student that will interact with the exhibit, a kindergartener. Reducing the size of the exhibit, the cost will also be reduced. Since the SciTech is funded by donations, the maintenance cost of the exhibit and any possible damage to the surroundings should be kept to a minimal.

The main constraints involved with designing an educational museum exhibit is the safety of the students and the how the students will interact. The safety is a large concern of all stakeholders, and any exhibit that has potential harm of any degree would not be used in a museum. The SciTech is also a mostly interactive museum where students can learn by interacting with the exhibits. The exhibit should encourage students not only to interact with the exhibit, but with each other. Science exhibits help the students to communicate science information and to work as a team. The social aspect naturally comes with exhibits that interest students. An interesting exhibit will gather some students, and those students will want to show their friends. Thus, the students begin teaching and learning from one another.

2.3 Design and Prototype

Once the background work is complete, the actual exhibit design can begin. All exhibits have a central theme. The theme for this particular exhibit is educational. Since the museum is mainly for students to come and explore science, the topic of the exhibit should follow the central theme of the museum and involve science and technology. The users and stakeholders should be considered when choosing a topic. A museum exhibit that does not keep in mind the audience will usually be less popular because it is not designed with the proper audience in mind. When the topic is chosen, modeling potential designs is possible. Several preliminary designs were created, and with each design the users were kept in mind. When one design seems to satisfy the needs of the users and stakeholders, the initial design was discussed with fellow peers. Discussion of the initial design with other peers can help final all the gaps and considerations that may have been missed. The discussion improved the initial design several times before a prototype was ready to be made.

The purpose of the prototype is to physically model the exhibit to observe the actual student interaction with the exhibit. Given the prototype will only be temporarily placed at SciTech; the material used was cheaper than the final product. For components of the exhibit that require selecting from a range of materials, Cambridge Engineering Selector (CES) was used to sort the materials in the desired manner. CES is a materials database program with information on processes and characteristics of the materials. With the help of the program, the materials can be separated into categories such as metals, polymers, and natural materials, and sorted by specific characteristics like thermal properties, electrical properties, or cost.

2.4 Testing and Modifications

After the prototype is completed, it can be tested be actual students. Since the client is SciTech, the best place to test the prototype would be at the museum. Students would be able to enter during their breaks and interact with the new exhibit. Observations were conducted on how well the project met the design requirements. Even though the majority of the observations are the designer's, it is important to receive feedback from the stakeholders. The curator and volunteers, who have worked with the general age group before, can provide immediate feedback following the observation.

The observations and feedback received as a result of the interaction with the prototype can be used to redesign the exhibit to fix any problems. It is preferable to observe over several days to see how different students interact with the exhibit, but in some cases, this is not possible. There are some days at the SciTech where no students came in during the break. The importance of redesigning the exhibit is to ensure the final product will be the best it can be with the time given. The final product will need be presentable since it is the new permanent exhibit replacing the prototype.

3 Results and Discussion

The main outcome was the final product, but in order to reach the final product several steps were taken as described in section 2. Each stage of the project yielded a result that affected future decisions. An important part is also to analyze the reasons the results occur so that future models and designs can be improved.

3.1 Topic Choice

Although the topic of the exhibit is different than what was requested of the curator, the decision came from observing student interactions and the California State Standards for K-6 grade students. The curator originally wanted an exhibit on graphene, a single layer of carbon chains, but the exhibit would not have another purpose besides an interesting exhibit for kids. Students are able to grasp the concepts being demonstrated with exhibits because they are related to their lives one way or another. To make the exhibit useful for all stakeholders, research was done on the California science standards. Combining the user personas, design requirements, constraints, and the science standards, the possible topics were narrowed down. Recalling one of the requirements was to reduce the possible damage to the surrounding area, all water options were eliminated. The moisture from a water exhibit can cause mold to grow and damage the technology exhibits if a leak were to occur. Also, an exhibit with a large amount of small parts was not considered because the cost to replace the lost pieces will accumulate and be difficult to manage physically and financially.

An interview with the science teacher at Bellevue-Santa Fe Charter School was conducted to further understand which science topic was the most difficult for students to understand without the assistance of visuals. Some topics included earth science, thermal energy, magnetism, the solar system, atoms, electricity, and natural resources. After some research on the scope of content the students would learn in the classroom and considering the involvement of materials science, the topics were narrowed down to earth science, magnetism, and electricity. Revisiting the California science standards for K-6 grade, electricity encompassed the widest range of standards. The exhibit will introduce students to simple circuits and the conductivity of different materials. Circuits allow the students to see the use of electricity, and understand that not all materials conduct electricity.

3.2 Design

The initial design was created to minimize the amount to space needed for the exhibit. The size of the sample the students would be handling was determined to be 6" x ¾" x ¼" to allow the younger students to easily grab the sample and for the curator and volunteers to spot the samples if it was misplaced within the museum. The exhibit was designed around the size of the sample. Overall, the design incorporated eight different stations, four circuits to test a single material and four circuits to combine two materials in a series. Keeping in mind the optimization of total size of the exhibit, a square design with each side as 2.5' was used. The 2.5' square was enough to have the single material circuits to be perpendicular to the sides of the exhibit and the series to be on the diagonals (Figure 2).

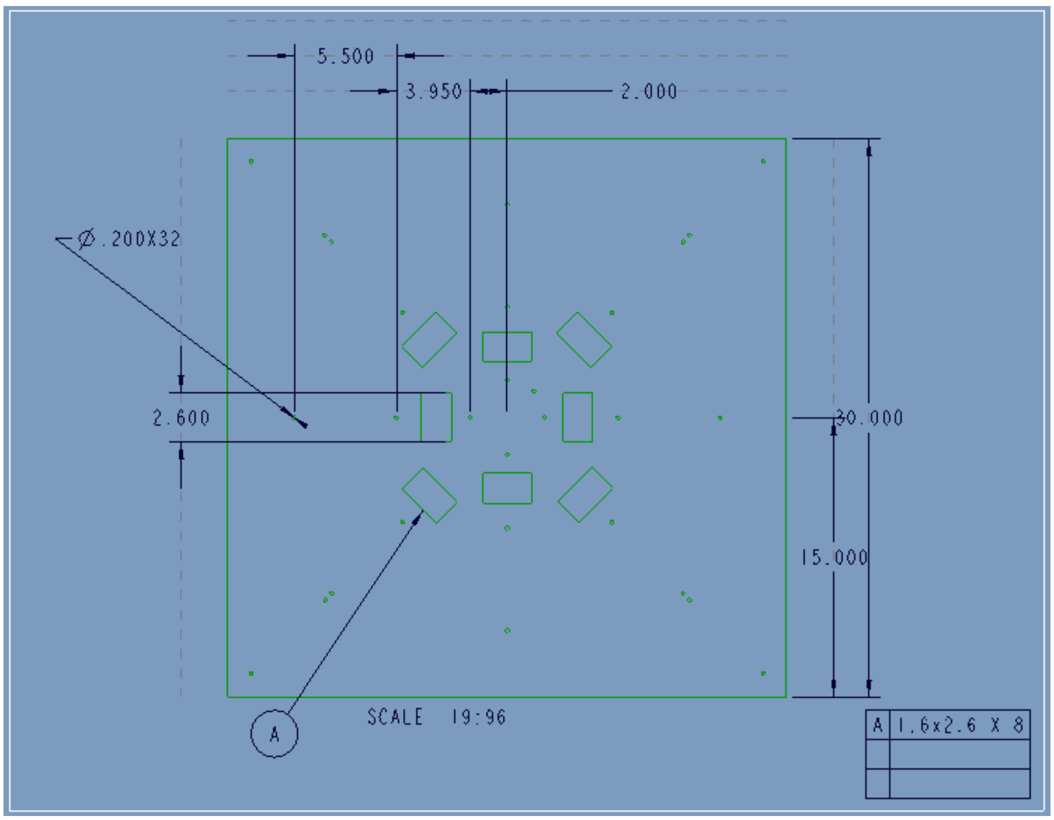

Figure 2. The initial 2.5' x 2.5' museum exhibit design contained eight circuits.

Once a computer draft was created, the exhibit seemed to have so much going on and looked crowded. The students do not need four of the same circuit to test the material. Although the design optimized the size of the exhibit, the interaction level was predicted to be low. The single material circuits would be a onetime test for each material and the spacing between each circuit would cause the students to crowd the exhibit. Since the exhibit interactions were predicted to be low, the students may only be inclined to interact with the exhibit once before moving on. Several problems were seen with the design and did not seem fit as a prototype.

The initial design needed to be modified to fix the problems. Even though the exhibit was supposed to optimize the size of the exhibit, there must be a balance between all of the requirements. The number of interactive stations was reduced and the single material circuit was replaced with parallel circuits (Figure 3). By increasing the number of materials needed to complete the circuit to two, students are now able to choose different combinations of sample and experiment with the conductivity of the materials. In order to show the completion of the circuits, LEDs were used as a qualitative indicator and ammeters were used as a quantitative measurement of current. The students would not be able to find the actual conductivity because it involves an equation too complex for the target age group. Instead, students will be able to know which material is conductive and which is not. Another feature added to the second design is a toggle switch. The switch allows the exhibit to be turned on and off, preserving the life on the LED and save energy.

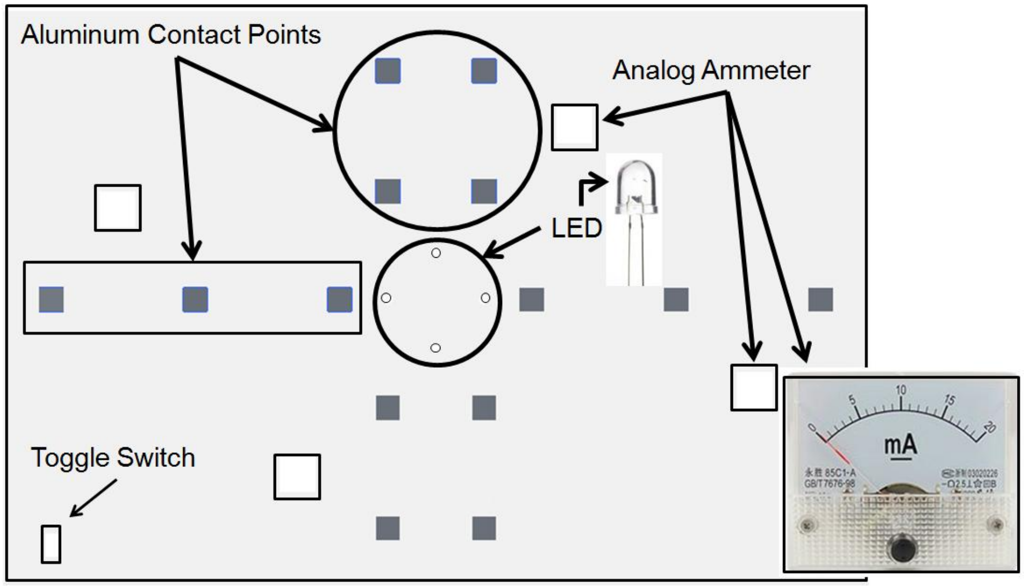

Figure 3. Components on the finished prototype place at SciTech for observations.

The theoretical interaction with the exhibit includes selecting a combination of two materials to place on the contact points in order to attempt to complete the circuit (Figure 4). The materials used for the samples include metals, polymers, and wood. The exhibit allows for other materials to be added or removed as needed. The students are encouraged to work together in discovering which combination would power the LEDs in the center. The design challenges the students to experiment and create hypothesis when the chosen materials work for a parallel circuit but not for a series circuit. The circuits are connected to a bread board which draws power from an external power source.

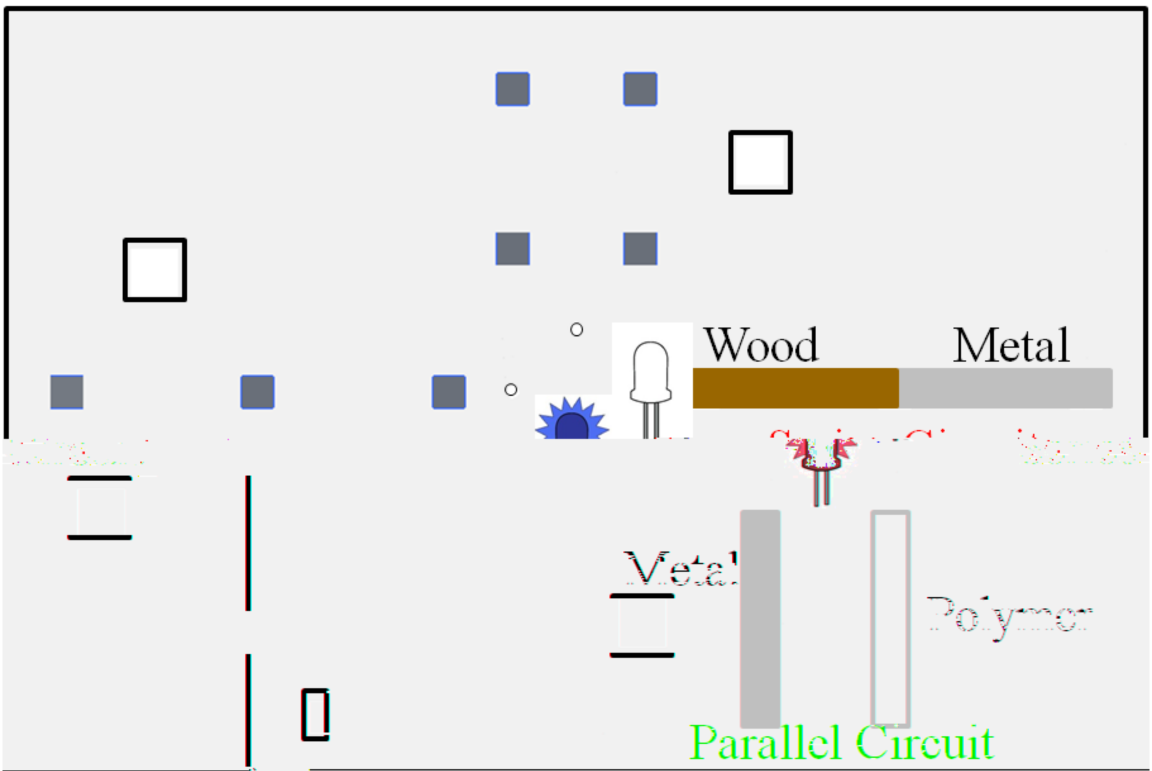

Figure 4. Diagram of how students will interact with the exhibit.

The second design met the requirements set for an interactive museum exhibit. A scaled model was created using ProEngineer to display the actual exhibit size with the components (Figure 5).

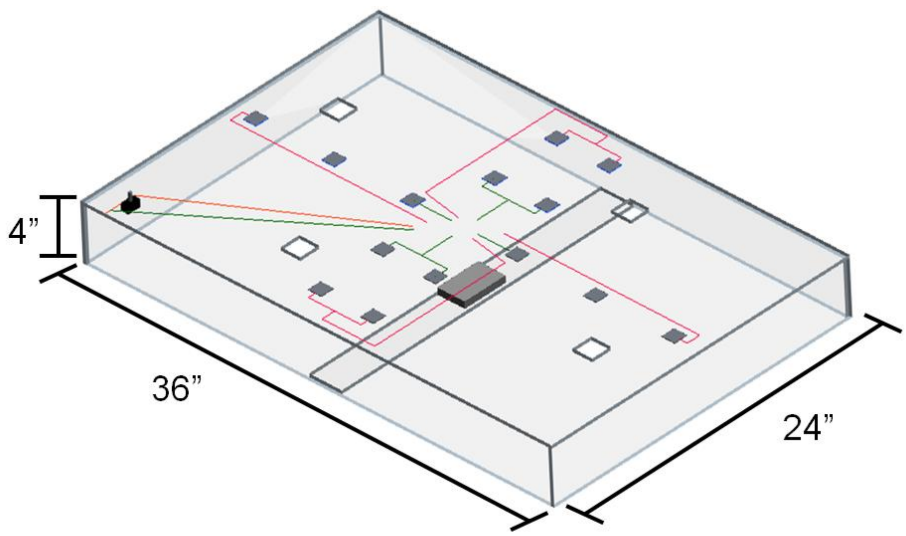

Figure 5. Complete ProEngineer model of the prototype design.

There is enough space on the top for wiring, and also for the students to interact without feeling too overcrowded. The height of the exhibit was chosen because of the given location to the exhibit at SciTech. The exhibit rests on a movable cart that is approximately three feet tall. The height of the cart limited how tall the exhibit could be. Any higher could possibly be too tall for the younger students.

3.3 Materials

The several samples were chosen from the general categories of metals, polymers, and wood. Students will be handling the material samples and using them to complete the circuit. With the aid of CES, the materials were separated into categories and sorted by resistivity; ρ. Resistivity (ρ) is inversely proportional to conductivity (σ), the property of interest (Eq. 1).

$$\rho = {}^{1}/_{\sigma} \qquad \text{(Eq. 1)}$$

For the metals, the selection criterion was to be low cost. Students will often times accidentally misplace or leave with the samples, and the samples would need to be replaced. It would not be ideal to spend a lot of money to buy a stock of silver samples even though it is one of the best conductors. A metal was also selected from each end of the graph (Appendix A- 1).

Each end of the graph listed expensive materials specifically because of their resistivity level as a metal. The metals that were chosen are stainless steel and copper due to their affordable cost and abundance.

The polymers had a different criterion since they were not expensive. For the polymers, the selection was based on the use of the polymer. Since some polymers that are not used unless for a specific purpose, the commonly used polymers were chosen from the graph (Appendix A-2). Students would not come in contact with some of these polymers until later in their lives. The purpose of choosing a polymer that the students can possibly interact with on a daily basis is to allow the students to make the connection from their life to what they are learning. Polystyrene is used to make commercial objects like toys and containers, and polyester is mainly used in clothing. These were the best choices in terms of examples of uses CES provided.

The supplier of the wood only had balsa wood that came in the desired rectangular shape. Since all of the materials were ordered from the same supplier, it was easier to use balsa, but other wood samples can be obtained in the future if there needed. There is a large difference in resistivity between each general category of materials (Table I).

Table I. List of Possible Materials from CES with Chosen Materials Bolded

Materials	Avg Resistivity (μohm.cm)
Polystyrene	**1.00×10^{26}**
Polymethyl methacrylate	9.95×10^{23}
Polytrafluoroethylene	9.95×10^{23}
Polyester	**9.95×10^{18}**
Polylactide	1.00×10^{18}
Polyhydroxvakaoates	1.00×10^{17}
Balsa	**1.00×10^{14}**
Nickel Super Alloys	142
Nickel-Chromium Alloys	135
Titanium	130
Stainless Steel	**82.8**
Copper	**29.5**
Gold	2.45
Silver	1.75

3.4 Circuitry

The second design contained a total of four stations; two parallel and two series circuits. Each circuit provided the option to test two different materials (Figure 6).

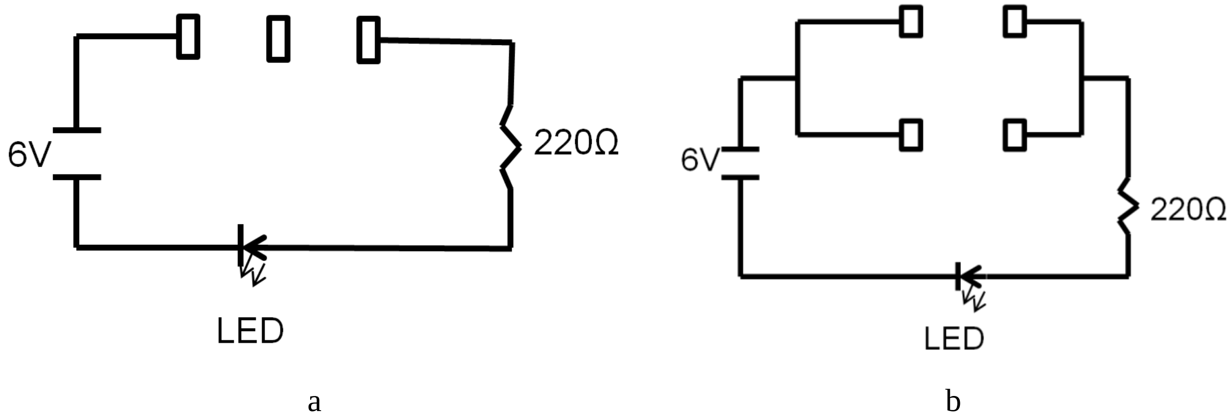

Figure 6. a) Schematic of a series circuit showing the two empty slots in a straight line. b) Schematic of a parallel circuit showing the empty slot of the materials side by side.

The materials the students will use with the exhibit were tested in an individual circuit to determine the current in the circuit. The metals were able to complete the circuit and power the LED, while the other materials were non conductive and did not power the LED (Figure 7).

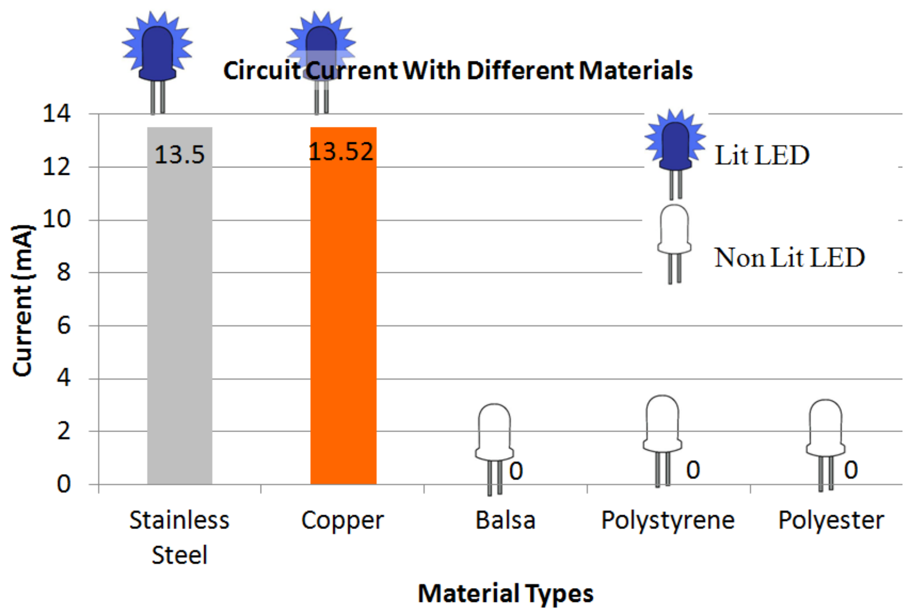

Figure 7. The current in the circuit containing each individual material showing which ones lit the LED. The two metal samples were able to complete the circuit lighting the LED while the other material were not conductive and did not light the LED.

Each circuit contains a 220 Ω resistor to protect the LED from burning out. Due to the high resistance, the ammeter shows stainless steel and copper to have a similar amount of current despite the different resistivity given in the CES chart. The wiring on the exhibit itself is connected to a bread board that obtains power from a 6 V power source and distributes the same voltage to each circuit. Each circuit requires two separate samples to complete the circuit to provide a larger range of experimentation possibilities. The circuits also contain a resistor, an LED, and an ammeter (to read the current).

3.5 Prototype

After all the materials are chosen and the design complete, a prototype was made (Figure 8). Since the prototype is not the final and permanent product at SciTech, cheaper material was purchased from the local hardware store. The prototype is made from ¼" plywood which was cheap, readily availability, and easy to manufacture with little prior skill. Many of the materials for the prototype were purchased from local stores such as Home Depot and RadioShack. The ammeters were ordered online from Amazon.com and the material samples were from McMaster-Carr. All the components for the prototype itself did not cost more than $100.

Figure 8. Completed prototype made from 1/4" plywood.

3.6 Testing

The completed prototype was placed at SciTech for observations and user interactions. A visiting school came during the morning, but the students were preschool students. The audience was a bit younger than the target range, but observations were still made on which exhibits attracted the younger students and several hypotheses were made such as moving parts, colorful, and entertaining. The prototype did not have anything fancy attached or showing since it was not the final product. During the break immediately following the preschool children, two students came in for the first time to interact with the prototype (Figure 9).

Figure 9. Observations were taken while the students interact with the finished prototype at the SciTech.

With no clear guide or instructional paper, the volunteer did her best to guide the students through the exhibit. The older students eventually understood the conductivity of materials, but still had trouble with understanding why the materials for parallel did not work for the series circuit. Once the students returned to class, the curator and volunteer gave some feedback on the prototype. They suggested adding some sort of light or sound to get students interested in taking time to look at the exhibit, possibly adding slots for the materials to be placed with labels, and possibly labeling the ammeters, contact points, LEDs, and other components on the exhibit so students can familiarize themselves with the terms.

3.7 Final Design

Combining the observations and feedback from the interaction with the prototype, the second design can be modified to make a final design. A minor change to the exhibit was an LED light added to one side of the exhibit that is powered by a battery source. The light is meant to attract the visitors and interest them in the exhibit. The main changes to the design were to the top surface of the exhibit (Figure 10).

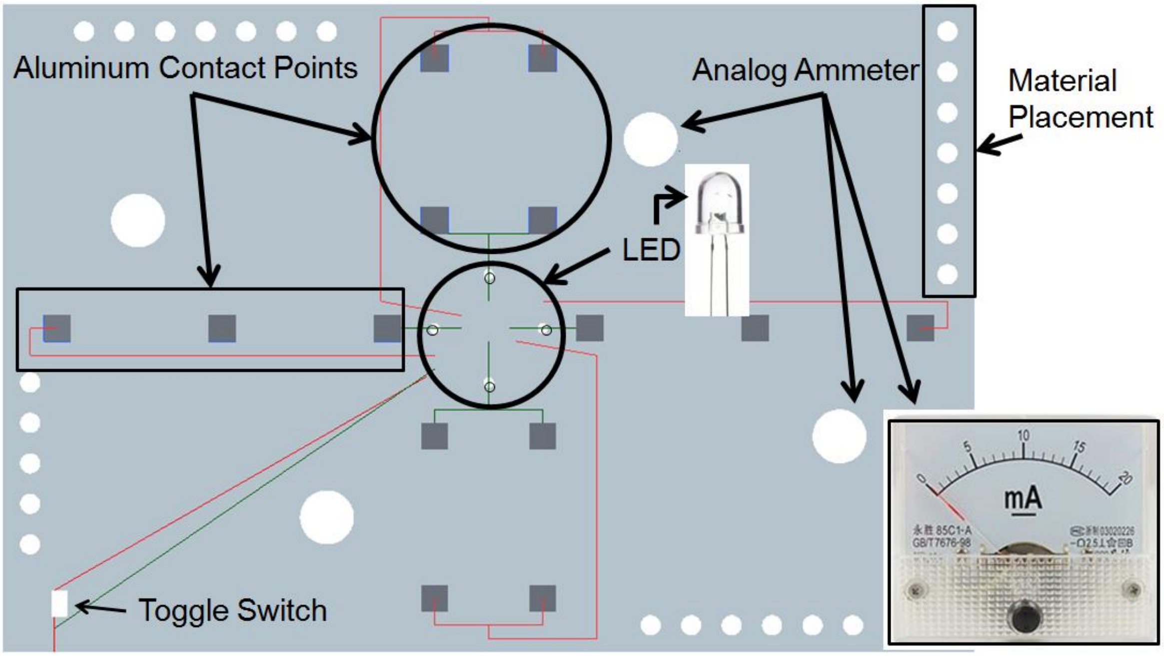

Figure 10. Components on the final museum exhibit design.

The students were placing the samples everywhere on the exhibit so holes were added to the final design to fit the materials. The students and volunteers were also lost on what each component was on the exhibit so labels were added to the final product, and a separate attachment showed how the exhibit works and the functionality and purpose of each component. The labels were printed on a sticker like material with an adhesive back. The final product is also made from transparent acrylic. Making the exhibit frame from transparent acrylic, the students can see wiring inside the exhibit. This allows the students to possibly create a hypothesis on how the circuits work based on how they are wired together. The transparent acrylic would also be more appealing to students than a wooden box with things on top. Another main change to the exhibit was the thickness of the material. The prototype was ¼” thick, but due to the lack of material from the manufacture, 3/16” acrylic was used. The functionality of the overall exhibit remained unchanged, but extra support needed to be added near the center of the exhibit to keep the top from sagging down. Two pieces of acrylic was added to the center breadboard

4 Conclusion

- The topic of the exhibit was chosen to introduce students to simple circuits and the conductivity of various materials. The exhibit combines the science standards for K-6 grade students and the exploration of materials science.
- An exhibit design was created with certain features that assist the students in learning.
  - The exhibit contained interactive stations for the students to explore and conduct their own experiments with other students.
  - The size of the exhibit was appropriate for students of all ages.
  - Several samples were chosen to allow the students to test combinations of different classes of materials.
  - The material samples were chosen based on certain criteria.
    - The metal samples were chosen because of the low cost of obtaining the material.
    - The polymers were chosen because the students have an opportunity to interact with the material in their daily lives.
    - The wood was chosen because the supplier only had one type that was similar in dimensions as the other samples.
- A full sized prototype was made from plywood for the students to interact and test.
  - Observations and feedback was taken and used to modify the design for the final product.
  - There was a clear difference in usage and understanding from the older vs. younger students.
- The overall design met the design requirements of being an educational interactive museum exhibit.
  - The safety of the students was maintained.
  - The exhibit successfully encouraged the students to interact with each other.
  - The students were introduced to two different types of circuits and learned that not all materials are conductive.

5 References

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6 Appendices

6.1 Appendix A – Materials Sorted by Resistivity in CES

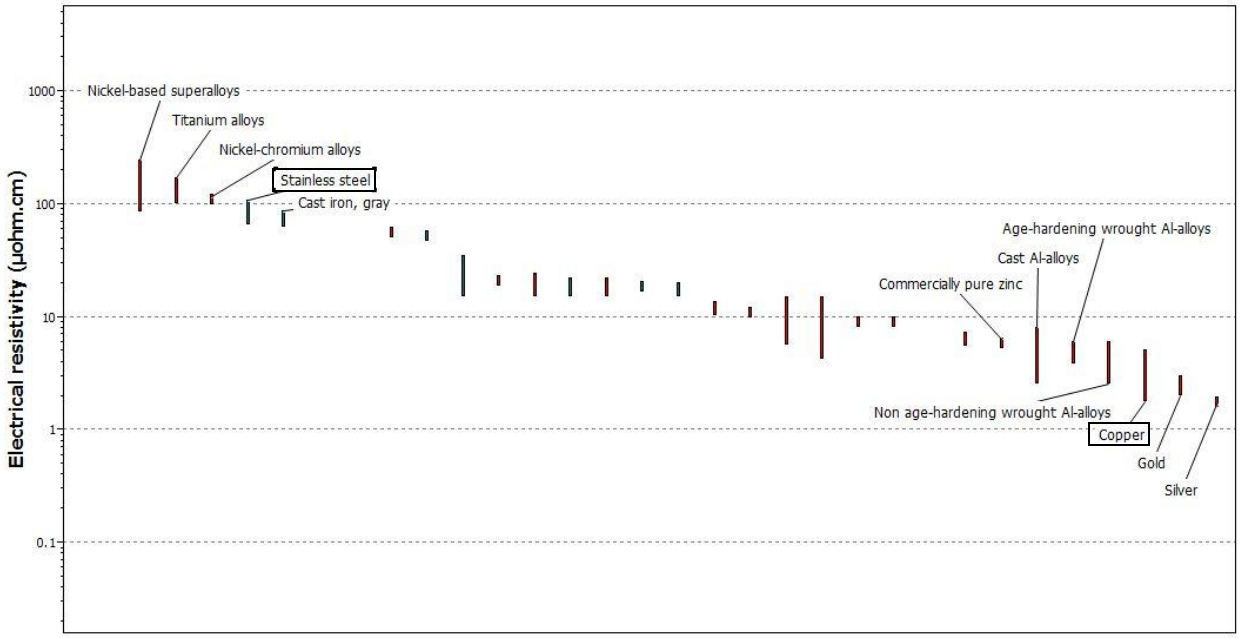

Figure A- 1. CES graph sorted the resistivity of metals from high to low.

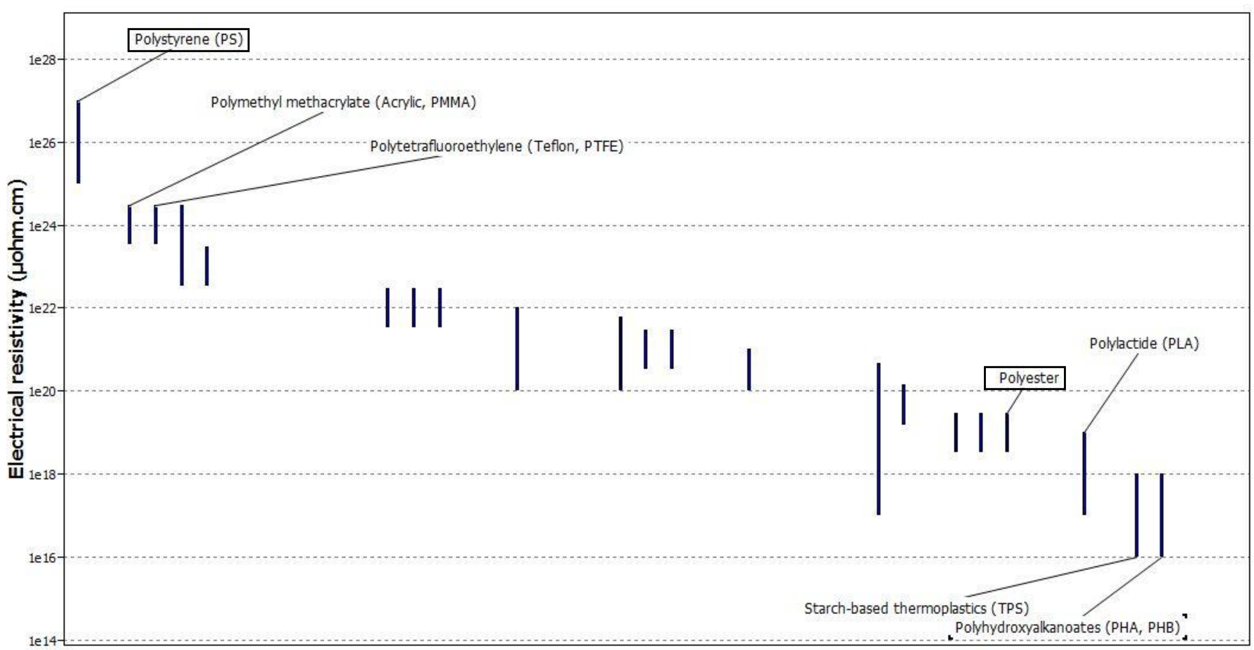

Figure A- 2. CES graph sorted the resistivity of polymers from high to low.